BRAKING SYSTEM

Background of the Invention

The present invention relates to braking systems and particularly to dynamic braking systems. More particularly, the present invention relates to braking systems utilizing the engagement of a brake plate against a brake disc to brake a rotating shaft.

Conventional braking systems typically include a brake disc that rotates with a rotating shaft and a brake plate that engages the brake disc to brake the disc and thereby slow and stop movement of the shaft. The rotating shaft may be a vehicle axle, a component of a powered door hinge, or any other rotating shaft that requires braking. The brake plate brakes the brake disc by relying either on friction between a face of the brake plate and a face of the brake disc or through positive mechanical engagement of teeth on the brake plate and corresponding teeth on the brake disc.

Summary of the Invention

Conventional braking systems that rely on friction can be unreliable in high-vibration environments where the spring or other mechanism that supplies the normal force between the brake disc and the brake plate relieves itself under the vibratory conditions and decreases the frictional force. Conventional braking systems that utilize the positive mechanical engagement of teeth on the brake disc and brake plate can suffer significant damage in high-velocity and high-vibration environments. The teeth of the brake disc or brake plate or both can break off in such environments. A braking system that provides and maintains sufficient braking force in a relatively high velocity, high-vibration environment will be welcome by users of such braking systems.

According to the present invention, a braking system is provided for braking a shaft mounted for rotation that includes a brake disc, a brake plate, and a spring. The brake disc is coupled to the shaft for rotation therewith and includes a disc face having a plurality of disc plateaus positioned around the circumference of the disc. Each disc plateau includes a disc ramp extending between the disc face and a top surface of the disc plateau. The brake plate is relatively stationary; thus, the brake disc rotates relative to it. The brake plate includes a brake face positioned substantially parallel and adjacent to the disc face and includes a plurality of plate plateaus corresponding to the number of disc plateaus. Each plate plateau

includes a plate ramp extending between the plate face and a top surface of the plate plateau. The plate ramps are angled relative to the plate face at the same angle at which the disc ramps are angled to the disc face. Recesses defined between consecutive plate plateaus are dimensioned to correspond to the disc plateaus such that the disc plateaus mate with the recesses. A spring biases the disc face against the plate face.

Additional features and advantages of the invention will become apparent to those skilled in the art upon consideration of the following detailed description exemplifying the best mode of carrying out the invention as presently perceived.

Brief Description of the Drawings

The detailed description particularly refers to the accompanying figures in which:

Fig. 1 is a cross-sectional view of the braking system in accordance with the present invention, including a brake disc and a brake plate;

Fig. 2 is a perspective view of the brake disc of Fig. 1; and

Fig. 3 is a perspective view of the brake plate of Fig. 1.

Detailed Description

Referring to Fig. 1, a braking system 10 according to the present invention includes a brake disc 12, which engages a brake plate 14. The brake disc 12 is coupled to an insert 17 that is coupled to a shaft 16. The shaft 16 is mounted in a sleeve 54 and bearing 56 combination for rotation with respect to a base member 18 that is relatively stationary within the system 10. By "relatively stationary" it is meant that the base member 18 does not rotate (as discussed below it does translate slightly) with respect to the majority of the parts of the system 10 or the overall device that utilizes the braking system 10. On the other hand, the shaft 16 does rotate with respect to the majority of the parts of the system 10 and the overall device.

Mounted for rotation, the shaft 16 could act as any of a number of things, including the hinge of an aircraft door or the axle of a vehicle, such as an airplane, etc., that creates a high-velocity, high-vibration environment. The brake plate 14 is mounted to the base member 18. Therefore, when the shaft 16 (along with the insert 17) rotates, the brake disc 12

rotates relative to the brake plate 14. A series of springs 20 bias the brake plate 14 against the brake disc 12 to provide a normal force between the two that engages the brake plate 14 with the brake disc 12 and brakes the shaft 16. The specifics of the engagement between the brake plate 14 and the brake disc 12 will be further discussed below. Some of the springs 20 include adjustment screws 48 that can be turned to adjust the force applied on the base member 18 by the springs 20.

With the braking system 10 positioned as shown in Fig. 1, the system 10 provides a braking force on the shaft 16. To release the braking force, power is supplied through cables 50 to a coil 52. When power is supplied to the coil 52, a magnetic field is created that attracts the base member 18 toward the coil 52 with sufficient force to overcome the force of the springs 20. The base member 18 is designed and constructed of metal to respond to the magnetic field created by the coil 52. As discussed above, the brake plate 14 is mounted to the base member 18 and, therefore, when the coil 52 is powered, the brake plate 14 also moves towards the coil 52. This moves the brake plate 14 out of engagement with the brake disc 12. If power to the coil 52 is lost or intentionally cut, the springs 20 again take over and force the brake plate 14 into engagement with the brake disc 12. Thus, the system 10 is considered "fail-safe" in that the system 10 brakes (i.e., engages the brake plate 14 to stop rotation of the shaft 16) if power is lost. However, it will be apparent to those of ordinary skill in the art that the system 10 could be designed to be "fail-secure" wherein the system 10 brakes when power is supplied to the coil 52.

Referring to Fig. 2, the brake disc 12 includes a connection hub 22 that is coupled to the insert 17 and, in turn, the shaft 16. The brake disc 12 is generally circular and includes a disc face 24 having three disc plateaus or disc teeth 26 projecting therefrom. Each disc plateau 26 includes two disc ramps 28 transitioning between the disc face 24 and a top surface 30 of the disc plateau 26.

The disc plateaus 26 are arranged generally around the circumference of the brake disc 12 and are equally spaced approximately 120° from each other. The disc plateaus 26 are sized so that they cover approximately one-half of the total circumference of the brake disc 12. Between consecutive disc plateaus 26, disc recesses 32 are created and cover approximately the other half of the circumference of the brake disc 12. The disc ramps 28 are angled approximately 10° relative to the disc face 24 to create a relatively shallow transition between the disc recesses 32 and the top surfaces 30 of the disc plateaus 26.

Referring to Fig. 3, the brake plate 14 has a plate face 34, including a series of plate plateaus or plate teeth 36 that generally correspond to the disc plateaus or disc teeth 26, discussed above. As with the disc plateaus 26, the plate plateaus 36, which include plate ramps 38 angled at approximately 10°, extend between the plate face 34 and a top surface 40 of the plate plateaus 36. In the illustrated embodiment, the disc ramps 28 and plate ramps 38 are angled at the same angle (i.e., approximately 10°). While angling the disc ramps 28 and the plate ramps 38 at the same angle is preferred as illustrated in the Figures, the ramps 28, 38 could be angled at slightly different angles (e.g., one at 9° and the other at 11°) or even more disparate angles (e.g., one at 5° and one at 20°). In all cases, however, the ramps 28 and 38 will be angled at shallow angles (i.e., between 5° and 20°).

Again, as with the disc plateaus 26, the plate plateaus 36 are spaced approximately 120° from each other around the circumference of the brake plate 14. A series of plate recesses 42 are defined along the circumference of the brake plate 14 between the plate plateaus 36 and cover approximately one-half of the plate circumference, with the plate plateaus 36 covering approximately the other half. A series of counter-sunk holes 44 through the brake plate 14 are used to mount the brake plate 14 to the base member 18 (see Fig. 1) so that the brake plate 14 is relatively stationary with respect to the base member 18. The insert 17 (and, thus, the shaft 16 attached to it) and brake disc 12 rotate relative to the brake plate 14 and the housing 18.

The connecting hub 22 of the brake disc 12 and the shaft 16 extend through a central aperture 46 of the brake plate 14, thereby positioning the disc face 24 adjacent the plate face 34. In this way, the top surfaces 30 of the disc plateaus 26 mate with the plate recesses 42 of the disc plate 14 and the top surfaces 40 of the plate plateaus 36 mate with the disc recesses 32 of the brake disc 12. Also, the disc ramps 28 are in engagement with the plate ramps 38. As the brake disc 12 rotates with the shaft 16, the disc plateaus 26 ride up the plate ramps 38 and onto the plate plateaus 36. The top surfaces 30 of the disc plateaus 36 then slide over the top surfaces 40 of the plate plateaus 36. The brake disc 12 must overcome the biasing force provided by the springs 20 to cause the disc plateaus 26 to ride up the plate ramps 38 and over the top surfaces 40 of the plate plateaus 36. The frictional force provided by the sliding engagement of the top surfaces 30 of the disc plateaus 26 over the top surfaces 40 of the plate plateaus 36, and the force provided by the positive mechanical engagement provided between the disc ramps 28 and the plate ramps 38 when the disc plateaus 26 are mated with the plate

recesses 32, provide the braking force to brake the shaft 16 and, thus, for example, a vehicle to which the shaft 16 is coupled. Once the braking process is complete, the positive mechanical engagement of the disc ramps 28 and the plate ramps 38, "locks" the shaft 16 in position, preventing further rotation of it.

As an example, the braking system 10 of the present invention could be used to brake the hinge shaft of a large cargo door on a transport aircraft. The system 10 would be powered, thereby releasing the brake plate 14 from the brake disc 12 to allow the shaft 16 to rotate while the door is being closed. As the door approaches its closed position, power would be removed from the system 10 and the springs 20 would force the brake plate 14 into engagement with the brake disc 12, as shown in Fig. 1. The interaction of the plate plateaus 36 against the disc plateaus 26 causes the shaft 16 to dynamically brake. That is, the shaft 16 may continue to rotate for a number of turns after the brake plate 14 has engaged the brake disc 12, but the engagement of the plateaus 26, 36 will cause the shaft 16 to begin slowing down and eventually stop. Once the shaft 16 has stopped rotating, the positive engagement of the plate plateaus 36 with the disc plateaus 26 provides a secure brake/lock preventing the shaft 16 from rotation even in the high vibratory environment of an aircraft. To help counter vibratory forces acting on the system 10, a number of plugs 58 made of an elastic material such as rubber, Viton, etc. are placed through the system 10 to help dampen vibration in the system 10. Even if the force of the springs 20 varies somewhat under the forces created by the vibratory environment, the positive engagement of the plateaus 26, 36 will not allow the brake disc 12 to rotate relative to the brake plate 14, which in turn means the cargo door will not move from its closed position. Thus, the at-rest state of the system 10, with power removed, provides a secure, closed state for the cargo door.

The foregoing description of the present invention has been presented for purposes of illustration and description. Furthermore, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, and the skill or knowledge of the relevant art, are within the scope of the present invention. The embodiments described herein are further intended to explain best modes known for practicing the invention and to enable others skilled in the art to utilize the invention in such, or other, embodiments and with various modifications required by the particular applications or uses of the present invention. It is intended that the appended claims be construed to include alternative embodiments to the extent permitted by the prior art.